TECTONIC STRUCTURE OF ALASKA AS EVIDENCED BY ERTS IMAGERY AND ONGOING SEISMICITY

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Problems

No data products have yet been received. This will not handicap the program for some time, however, because the investigators still have some untreated data from the original study.

Accomplishments

Work has continued along the same lines as in the original investigation, with larger areas of Alaska being studied in order to achieve an overall impression of the general tectonic framework. A mosaic of the greater part of the state has been constructed, utilizing some 70 images. Overlays for this mosaic were made, showing the principal tectonic features, and linears which are felt to be of tectonic origin. Some of the findings are given in the section on Significant Results.

Future plans include expanding the study area around the margins of the present one. This will include the tectonic belts of the Brooks Range to the north and the faults of the Kuskokwim area to the southwest.

In the months ahead, it is anticipated that the investigators will utilize LANDSAT imagery as an aid in evaluating different potential sites for a new state capitol. This will be done on a cost-sharing basis with the state of Alaska in cooperation with the Alaska state capitol relocation committee.

Since the expiration of the ERTS-1 program, an incident has occurred which dramatizes the usefulness of remote sensing in construction planning. During that program, we had contended, both at meetings and in publications, that it appeared a fault intersected the Yukon River near the site of the proposed bridge and oil pipeline crossing. Construction of the bridge was begun last year, and it was found that a fault gouge zone underlay the planned location of one pier. Design modifications are now being made which will cost an estimated $2 million.

Significant results

See attached article. This article will appear this year in a volume published by the University of Utah press entitled "Proceedings of the First International Symposium on the New Basement Tectonics."

Publications

See above.

Recommendations

None.

Funds expended

$8,900

Data use

None received.

TECTONIC LINEAMENTS AND PLATE TECTONICS IN SOUTH-CENTRAL ALASKA

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ABSTRACT

The seismically active portion of south-central Alaska is divided into four roughly equal portions by three large scale strike-slip faults which traverse the state from east to west. Similarities in the alignment of linears within each of these segments suggest that they may have similar histories of deformation, with the deforming mechanism being the underthrusting of the north Pacific lithospheric plate beneath the Alaska mainland. There is evidence to postulate that the relative movement between the continent and oceanic plate has been progressively transferred southward between the major fault systems.

INTRODUCTION

It has now been adequately demonstrated that the seismicity and configuration of the Aleutian arc system can be related to the processes of sea-floor spreading. It is less obvious how plate interaction relates to the seismic zone of central interior Alaska.

Recent studies (e.g., Davies and Berg, 1973; VanWormer et al., 1974), expanding on the observations of earlier workers (St. Amand, 1957; Tobin and Sykes, 1966), disclose that the Benioff zone, representing the area of subduction of the northwesterly moving north Pacific plate, follows the trend of the Aleutian trench to a point south of Kodiak Island, where it deviates from the bathymetric trench and follows a course through Shelikof Strait, Cook Inlet, and the Susitna River lowlands to a point north of Mt. McKinley (Fig. 1). Cross sections reflecting hypocentral distribution of earthquakes show that the Benioff zone clearly extends far inland (Fig. 2). Thus, the northeastern terminus of the Aleutian trench does not appear to be closely associated with the Benioff zone, as it is in the rest of the Aleutian arc. Instead, the northeastern corner of the subducting plate underlies the great bend in the Alaska Range.

From east to west within this bend, earthquakes grade in depth from shallow to intermediate, presumably reflecting the downgoing slab. North of the Alaska Range, all earthquakes are shallow, but their contemporaneity in time and proximity in space with the deeper events suggest that they, too, must be a product of transmittal of stresses arising from plate movement and subduction.

It is the purpose of this paper to suggest a possible relationship between structural lineaments visible on ERTS-1 imagery and the stresses arising from present and past plate interactions.

FAULT AND LINEAMENT PATTERNS

The ease with which persistent lineaments can be identified on ERTS-1 imagery has now been acknowledged by the scientific community. Most of the major faults which have been mapped by surface surveys in Alaska are obvious on an ERTS mosaic (Fig. 3). The structure of the region is clearly dominated by three major right lateral strike-slip fault systems. These are, from the north, the Tintina-Kaltag, Denali, and Castle Mountain fault systems (Fig. 5).

Present evidence indicates that approximately 400 km of offset occurred on the Tintina fault during the Paleozoic and Mesozoic eras, with most assigned to Cretaceous time (Foster et al., 1974; Roddick, 1967; Grantz, 1966). In contrast, displacement along the Kaltag fault has been given by Grantz as about 140 km, primarily in late Cretaceous time. The nature of the connection between the Tintina and Kaltag faults is questionable, with numerous splays from both faults being known in the area. These splays may account for some, or all of the discrepancy in the relative magnitudes of displacement along these faults. No data are available regarding possible displacement on the Teslin lineament (Aho, 1959).

Recent work by Turner et al. (1974) and by Forbes et al. (1974) indicates that approximately 400 km of right lateral offset has occurred on the Denali fault east of Mt. McKinley since the end of the Cretaceous. However, Grantz (1966) indicates that offset to the west of Mt. McKinley is only 100-115 km, so that a similar discrepancy exists as with the Tintina-Kaltag system, implying possibly similar deformational histories. Richter and Matson (1971) have suggested that the Denali fault east of its intersection with the Totschunda (Fig. 5) is presently inactive, and that relative motion between the Pacific plate and the continent has been taken up on the Totschunda fault since Holocene time.

Grantz (1966) further reports up to a few tens of kilometers of right lateral offset on the Castle Mountain fault dating from Late Cretaceous to Early Tertiary, with at least one splay at the east end of the fault active in post-Miocene time. The western extension of the fault (called the Lake Clark fault by most workers) is represented by a strong lineament on the ERTS-1 imagery. While its possible connection with the Castle Mountain fault is in question, the Lake Clark fault is well documented in its southwestern portion.

To recapitulate, the dates given by various workers for offset on the major fault systems seem to indicate that the major episodes of transcurrent movement have been sequentially transferred from the north to the south. Seismic evidence seems to bear this out, since the Tintina fault system is only slightly seismically active, the Denali moderately so, and the southern part of the state is extremely active, seismically (although the seismicity is not necessarily restricted to the Castle Mountain fault).

Turning our attention now to the lesser lineaments visible on the imagery (some of these are mapped faults, but the majority are not), we find that some criteria must be impsed in order to restrict the number of mapped lineaments to those which may have structural significance on the scale of the problem. Accordingly, for the present study, only those linears longer than 8 km (approximately 1/4 in. on the original mosaic) were considered. In general, linears which did not cross a drainage divide were also ignored. In order to check the validity of picking apparent lineaments from the imagery, a comparative analysis was made by identifying linears on the 1:250,000 quadrangle maps of two topographically dissimilar areas covered by the mosaic. Qualitatively, the results of comparing lineament patterns obtained from both sources show generally good agreement, particularly in that the same tectonic trends appeared in both presentations.

Figure 4 is a tracing of all the linears which were picked on a 1:1,000,000 ERTS mosaic of the study area. Approximately 60 images were utilized. While a fracture origin is assumed for the linears in most cases, other recognizeable features may be due to a variety of structural elements. As an example, the curving linears in the northeastern part of the mosaic are primarily folds, although they are cut by a remarkably straight feature of unknown origin.

The sketch map of Fig. 5 shows the major fault systems of the state, and the related features which we feel to have the most important bearing on the present problem. Note in particular the following characteristics:

(1) The overall similarity in size and shape of the zones between the major faults (the Kobuk trench near the northwestern edge of the scene would also seem to be a member of the set).

(2) The tendency of prominent linears to intersect the major faults obliquely from the south or southwest in the area of greatest bend in tectonic grain.

(3) The intersection of the Denali and Tintina faults by linears (the Totschunda fault and Teslin lineament, respectively) at approximately the same angle and in the same general location with respect to the overall tectonic framework.

(4) The appearance of what seem to be conjugate fracture systems near the area of greatest bend in tectonic grain in the northernmost three segments. The histograms of Fig. 6 depict the general characteristics of these fracture sets.

INTERPRETATION AND SPECULATION

It would seem obvious that each of the segments bounded by the major faults has experienced the same, or a similar deformational history. The scant evidence available from seismic and field studies suggests that these movements may have been imposed sequentially from the northern segment to the southern (although considerable overlap in time was experienced). The uncertainty of dating onset, duration, and possible cessation of movement on each of the major faults, however, renders such a conclusion highly speculative. While transferral of motion from the Tintina fault to the Denali appears plausible based on the dating information available, a similar transferral from the Denali to the Castle Mountain system must of necessity be based primarily on the relative seismicity of the two systems, since movement on both of them appears to have occurred since the Cretaceous.

It is seen on Fig. 5 that the bisectors of the dihedral angles formed by the conjugate fracture sets cross the zones with approximately the same orientation. Each set seems to be related to the adjacent major fault in the same manner. In general, the areas in which the conjugate sets occur are approximately in the same position relative to the bend in the next major fault to the south. Further, the bisector of the acute angle tends to be approximately normal to the major fault at that point. It can be hypothesized that such a bend in a strike-slip fault can become a center of compression, and that a radial stress field centered at the bend would have the appropriate orientation to generate the conjugate set of fractures. The southernmost of these fracture sets occupies an area overlying a corner of the present Pacific plate. An explanation for the northernmost two sets might be that they represent earlier positions of the plate corner. There is nothing in the geometry of the major faults and associated elements to contradict this, although it should be noted that if these areas were actually once associated with a subduction zone, they are no longer so, since only shallow earthquakes occur there.

Alternatively, it might be argued that since the bisectors of all three fracture sets strike at nearly the same azimuth, they were all formed at the same time under the same stress system. Determining the age of the fractures is therefore important in resolving the question of sequential or simultaneous formation. Further, considering that: (1) the present corner of the north Pacific plate is not actually determined by the Denali fault, but extends somewhat to the north (VanWormer et al., 1974), (2) there is no clear evidence of fossil subduction zones north of the present one, and, (3) the Denali and Castle Mountain faults appear to have been active at the same time, it can be argued that the geometry of these faults is entirely independent of the plate corner and that the present relationship is coincidental. In this case, the difference in seismicity might be due to some of the motion of the Pacific plate being taken up along some of the older faults to the north.

A final corollary which might be hypothesized is that, if the Totschunda fault is actually taking up the movement between the Pacific plate and the continent as suggested by Richter and Matson, then an interpretation of the Teslin lineament is that it bore the same relationship to the Tintina fault at an earlier time that the Totschunda bears to the Denali at the present.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

1. Location map showing areas of interest referred to in text.

2. Earthquake hypocenter distribution in sample 50km thick slab looking northward from point near Yentna River. Seismic zone dips to the west under the Alaska Range. Data are from 1971-1973.

3. Mosaic of ERTS-1 images obtained in region of interest.

4. Overlay of linears picked from imagery at scale of 1:1,000,000. See text for details.

5. Principal features on imagery which are discussed in text. Circles are general areas of apparent conjugate fracture sets, with arrows denoting directions of maximum compressive stress.

6. Histogram revealing characteristic strike directions of lineaments within the three areas circled in Fig. 5. From the north, these are the southern Brooks Range (solid circles, 101 lineaments), the Rampart-Ray Mountains area (open circles, 134 lineaments), and the western Alaska Range (solid triangles, 427 lineaments). The additional peak in the Rampart-Ray Mountains plot at around 70°-80° reflects the Kaltag fault and associated parallel lineaments which seem to have little effect on the conjugate set.

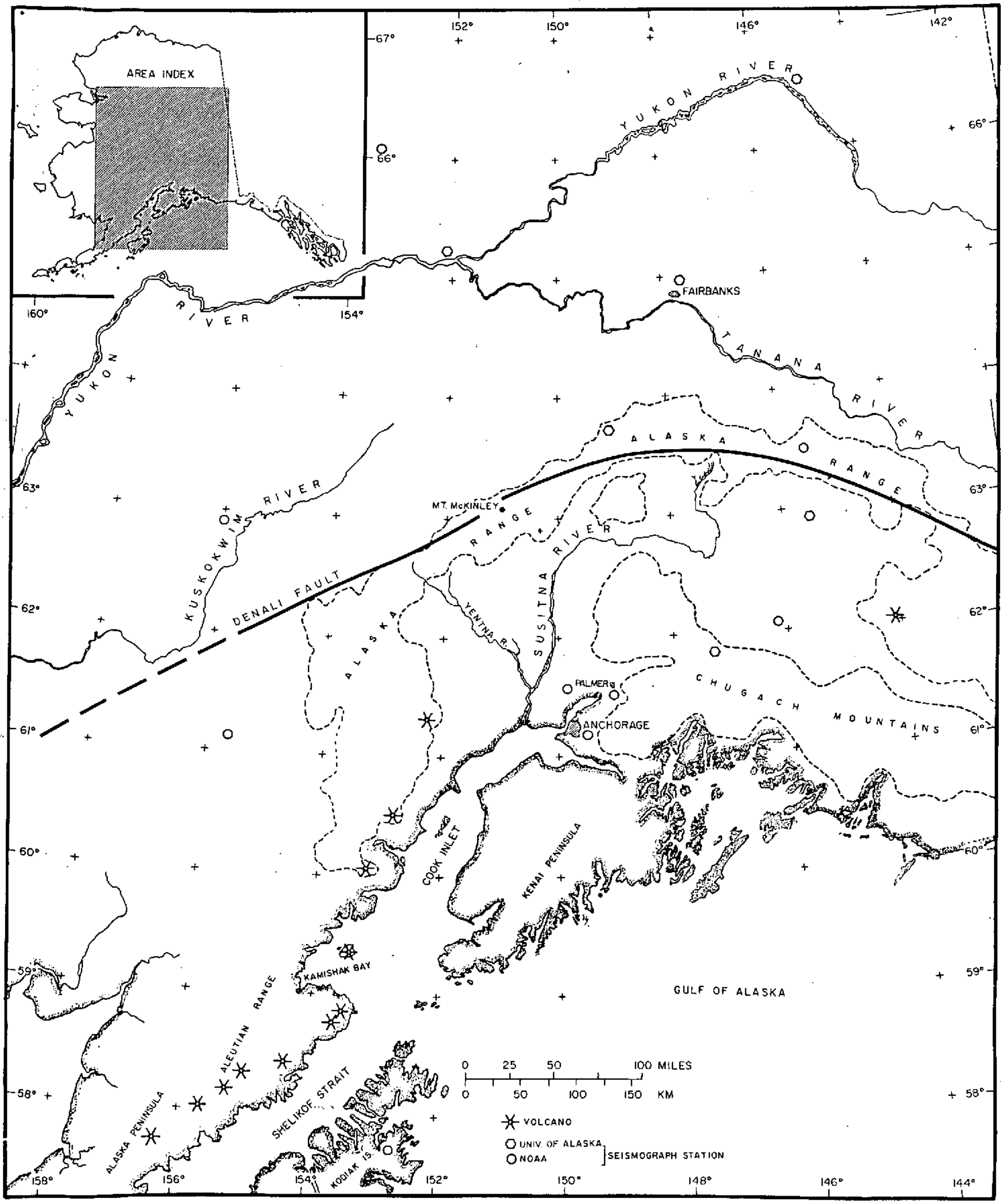
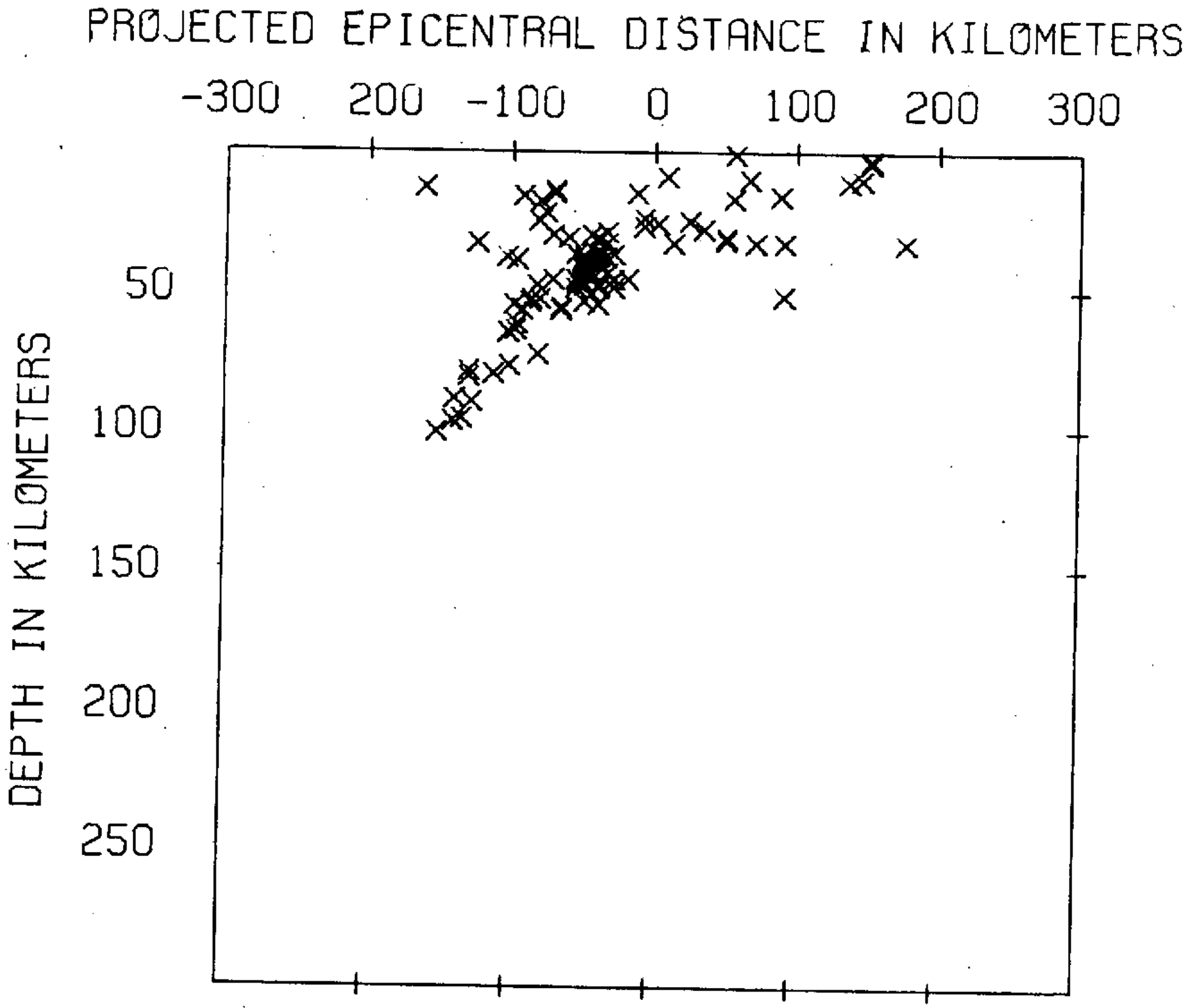

AREA INDEX
YUKON RIVER
FAIRBANKS
TANANA RIVER
KUSKOKWIM RIVER
ALASKA RANGE
MT. McKINLEY
DENALI FAULT
SUSITNA RIVER
YENTNA R.
PALMER
ANCHORAGE
CHUGACH MOUNTAINS
COOK INLET
KENAI PENINSULA
KAMISHAK BAY
ALEUTIAN RANGE
SHELIKOF STRAIT
ALASKA PENINSULA
KODIAK IS.
GULF OF ALASKA
0 25 50 100 MILES
0 50 100 150 KM
VOLCANO
UNIV. OF ALASKA
NOAA
SEISMOGRAPH STATION

Figure 1



PROJECTION ORIGIN: 61.37N 148.97W

LIMITING ORIGIN: 62.00N 148.97W

AZIMUTH OF PROJ PLANE: 0 DEGREES

NUMBER OF EVENTS PLOTTED: 97 OF 165

Figure 2

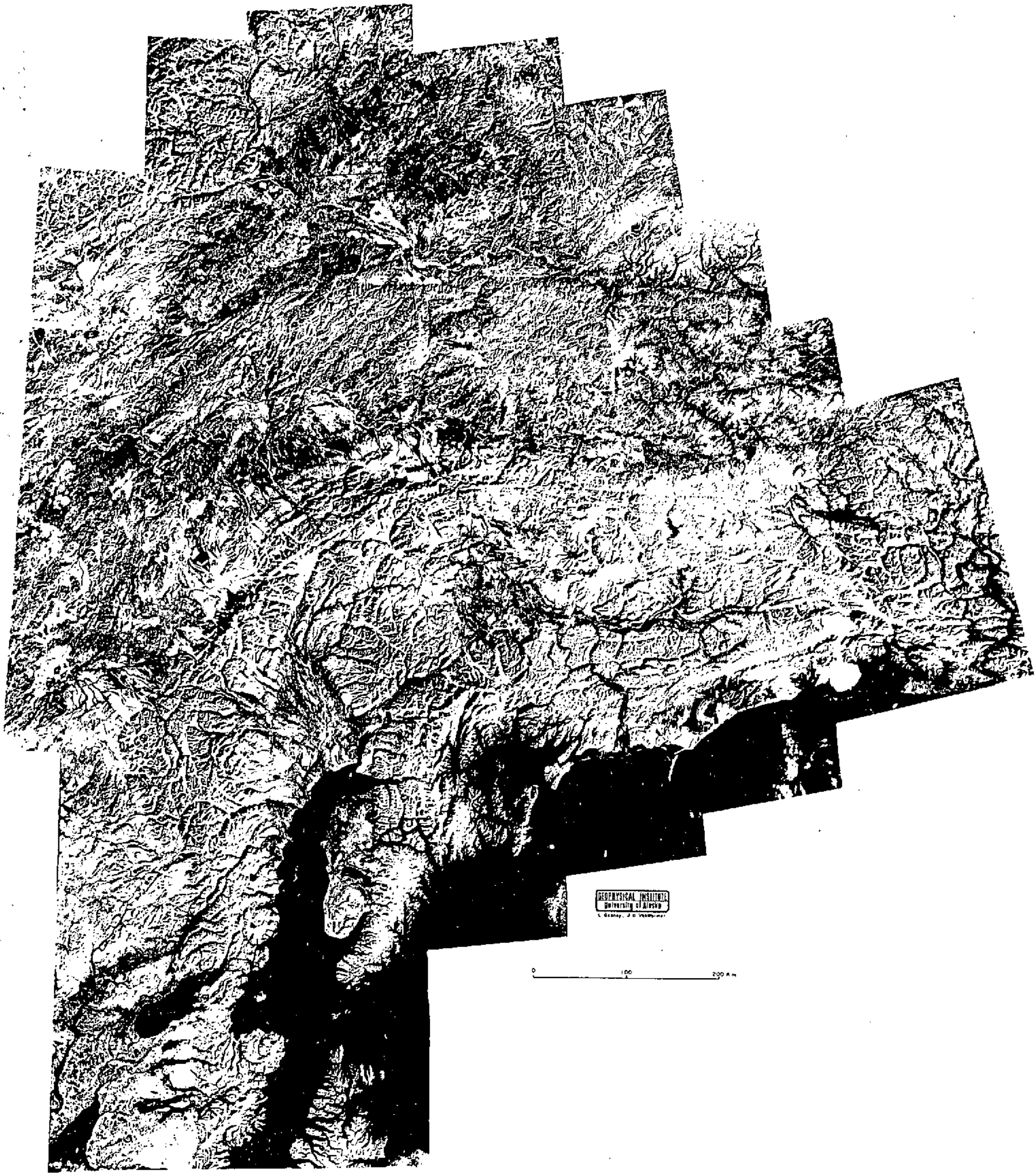


Figure 3

Figure 4

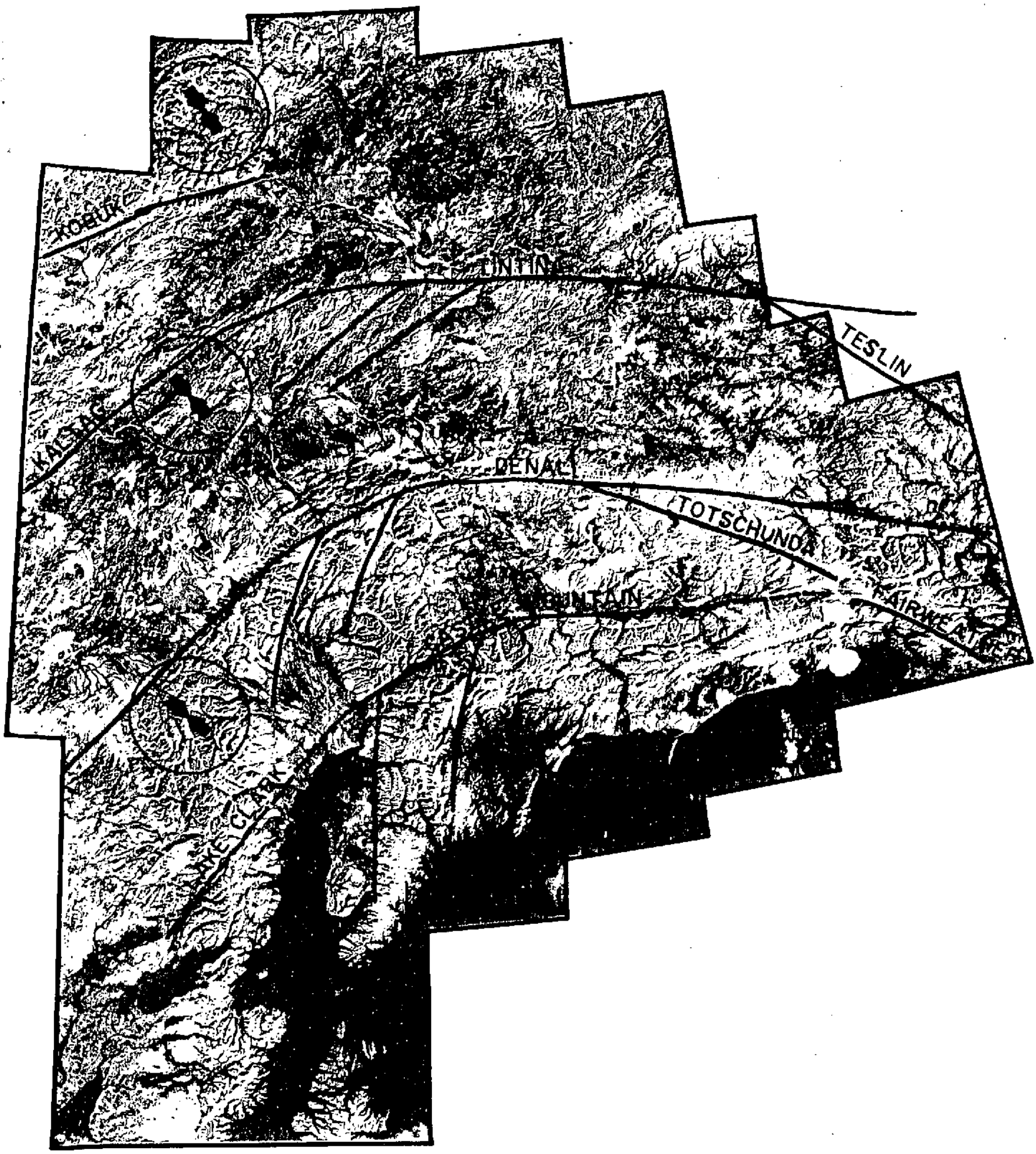


Figure 5

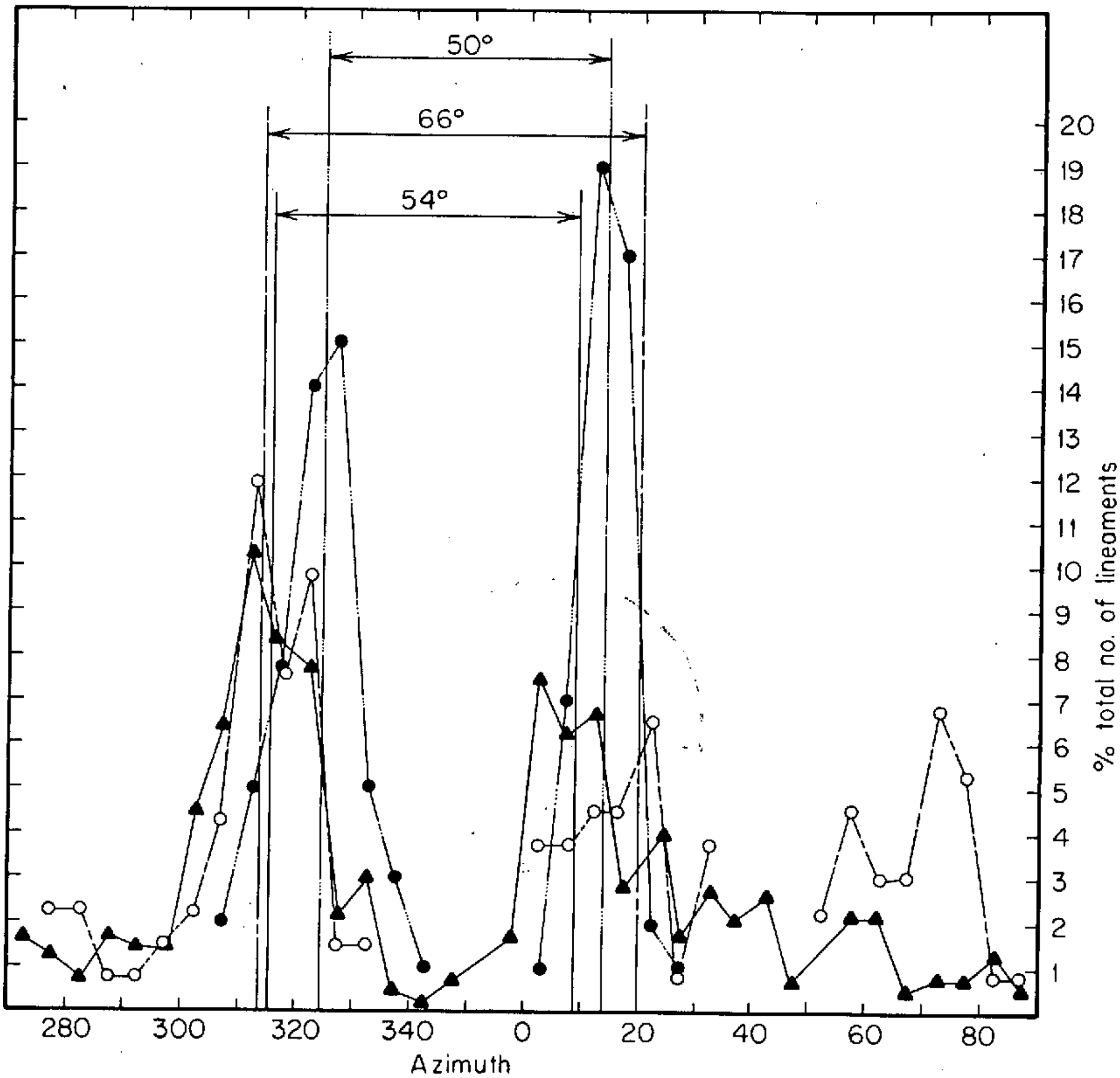

50°
66°
54°
280
300
320
340
0
20
40
60
80
Azimuth
% total no. of lineaments
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 6